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Is Biofuel a Feasible Long-Term Chief Energy Source? A Global Perspective

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Is Biofuel a Feasible Long-Term Chief Energy Source? a Global Perspective

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ABSTRACT: This scientific paper examines the feasibility of officiating biofuels as the future chief energy source of the world. It weighs the pros and cons of the four different generations of biofuels that have been discovered over time, explaining how the raw materials used in each generation determines each individual level of long-term sustainability. It then further analyses both general advantages and disadvantages, comprising of economic, social, health and environmental impacts; giving the reader an unbiased perspective. Few case studies have also been reviewed to better understand the implications of drawing energy from biofuels, as well as the current state of technology that were utilized in this examples. With the countries at varying stages of development, certain generation of biofuel would inevitably be deemed more feasible than others. Recommendations have been made regarding which generation of biofuel would be most efficient and environmentally friendly in the long run. Biofuels in general, are the lesser of two evils. Negative impacts are inevitable, but one has to eventuallytake the bigger picture into consideration - a more sustainable source of energy as compared to fossil fuels.

KEYWORDS: biofuel, sustainable energy, algae, microbes, bioreactors, environmental impacts

I. INTRODUCTION

With the continuous and rapid multiplication of the global population, consumption overpopulation leads to increased ecological footprint. Thus, to cater to demands of the populace, burning non-renewable sources like fossil fuels creates energy.Fossil fuels are extremely popular due to its availability, “high calorific value” [1] and relatively cheap cost. However, man’s over-reliance on this energy source is resulting in a shortage, gradually worsening with time. In addition, the disadvantages of burning fossil fuels are aplenty, through air pollution by emitting greenhouse gases (GHG)such as carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NOx), sulphur oxides (SOx) and particulate matter (PM) [2].This depletes the ozone layer and produces acid rain, causes health hazards due toinhalation of toxic gases, and aquatic hazards through potential oil spills [3] As such, human demands are met at the expense of Earth. Thus, with increased urgency to create an environmentally sustainable society for future generations, tapping onto cleaner alternatives like biofuel as an energy source is becoming popular both in developed and developing countries (Table 1).By gaining more insight on its scientific characteristics, this report will further look into the viability, as well as challenges, of implementing this potential chief energy source, especially utilizingitsmore recent third and fourth generations.

Uses of Biofuel

A smoother running journey by automobile is possible due to the increased efficient use of chemical energy and also the reduced emission of toxic gases, thus being Europe’s most popular choice of fuel. Contributing to just “over 1.5% of global transport fuels” [4], biofuel can also be used to generate heat and electricity— cooking using induction stoves, charging electronic devices and pumping water from wells [5].

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II. LITERATURE REVIEW: BIOFUEL GENERATIONS

First Generation

First generation biofuel is not conventional and also the most commonly produced and used globally. As seen from [6], it is derived from processing edible feedstock like sugarcane or vegetable oil and various examples include Biodiesel, Biogas and Bioalcohol. Despite having general benefits such as lowering greenhouse gas emissions and providing energy security, there is a nagging concern on the stress that its production has on the population's commodities. Due to its active competition with food sources, global food security is compromised on and is the huge driver of hikes in food prices. Apart from food security issues, first generation biofuel is also accountable for deforestation practices for plantation to grow crops, which is harmful to biodiversity, contributing to water scarcity in developing countries and also exorbitant production prices. In [4], food security will constantly remain an obstacle to overcome as long as these first generation biofuel reigns as the most popular choice.

Table 1: Past and Present Usage and Future Prediction

World Biofuels Consumption

	2004	2010	2015	2030
OECD	**8.90**	**30.50**	**39.00**	**51.80**
North America	7.00	15.40	20.50	24.20
United States	6.80	14.90	19.80	22.80
Canada	0.10	0.60	0.70	1.30
Europe	2.00	14.80	18.00	26.60
Pacific	0.00	0.30	0.40	1.00
Transition Economies	**0.00**	**0.10**	**0.10**	**0.30**
Russia	0.00	0.10	0.10	0.30
Developing Countries	**6.50**	**10.90**	**15.30**	**40.40**
Developing Asia	0.00	1.90	3.70	16.10
China	0.00	0.70	1.50	7.90
India	0.00	0.10	0.20	2.40
Indonesia	0.00	0.20	0.40	1.50
Middle East	0.00	0.10	0.10	0.50
Africa	0.00	0.60	1.10	3.40
North Africa	0.00	0.00	0.10	0.60
Latin America	6.40	8.40	10.40	20.30
Brazil	6.40	8.30	10.40	20.30
World	**15.50**	**41.50**	**54.40**	**92.40**

Source: World Energy Council, 2010

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Second Generation

As a direct solution to the negative environmental impacts and high prices posed by first generation biofuel, second generation biofuel becomes a more sustainable choice. They utilize inedible plant crops known as "lingo-cellulosic feedstock", including agricultural and forest residues like wood process wastes and other dry plant matter. In areas with limited supply of lingo-cellulosic feedstock, [7] shows that vegetative grasses and short rotation forestry crops are viable alternatives. Although land is still necessary for crop growth and available land is gradually decreasing, high quality land is not a priority. Considering the rapid rate of this crop growth that produces a larger yield without compromising on food for the population, there would be a decreased dependency on water supplies and agricultural chemicals, which are harmful to the environment (Table 2). However, as these non-food crops are not usually cultivated or grown, they pose a threat to existing crops as an invasive species that compete for nutrients which endangers the ecosystem [8]. Another major drawback for second generation biofuel is that they are less compatible to be used on a commercial scale. One such example is biodiesel derived from jatropha oil, a non-food crop.While jatropha oil can be used directly in stationary engines of tractors, utilizing jatropha oil in modern diesel car engines would require more effort becauseit has to undergo a special process called 'Transesterification'. The conversation of 100kg of jatropha oil will yield 95kg of biodiesel [9], which means the process gives promising results.Since they are less commercialized, their benefits are not as ideally recognized. However, based on Sims et al. [4], with the growing investment in research of second generation biofuel to overcome economical and technical difficulties, it will gradually become more prominent in the industry.

Generation	Crop	Product (Yield)	GHG Emissions*	Use of Resources			
				Water	Fertilizer	Pesticide	Energy
1	Corn	Ethanol	81 to 85	high	high	high	high
1	Sugarcane	Ethanol	4 to 12	high	high	med	med
2	Switch Grass	Ethanol	-24	med - low	low	low	low
2	Wood Residue	Ethanol, Biodiesel	N/A	med	low	low	low
2	Soybeans	Biodiesel	49	high	low - med	med	med - low

Table 2: Comparison of Resource Usage During the Production of First and Second Generation Biofuel & GHG Emissions

* CO_2 (in kg) created per mega joule of energy produced

Source: Gas, 2014

Third Generation

Judging the varying levels of agricultural limitations of both previous generations, third generation biofuel eliminates harm done to agricultural land because they are solely generated from lipid in algae, also known as "Algal Biofuel". The diversity in which algae can be cultivated, in open ponds, closed-loop systems or photobioreactors, deems it an extremely feasible alternative. Furthermore, it is believed that no other crop can match up to algae's product quality or diversity. For example, not only is algae capable of producing shockingly high yields of up to 20 times that of first and second generations, it can be "genetically manipulated"[10] to produce types of biofuel from all generations. Algae can also directly convert carbon emissions from industrial plants to usable fuel, reducing air pollution. Thus, algae is said to be efficient. However, as with any other situation, there is a downside to algae biofuel. In order to support rapid growth, a substantial amount of water, nitrogen and phosphorus must be present. Withlarge-scalecultivation, comes the need for mass fertilizer production, resulting in colossal greenhouse gas emissions. Hence, the initial benefits of algae

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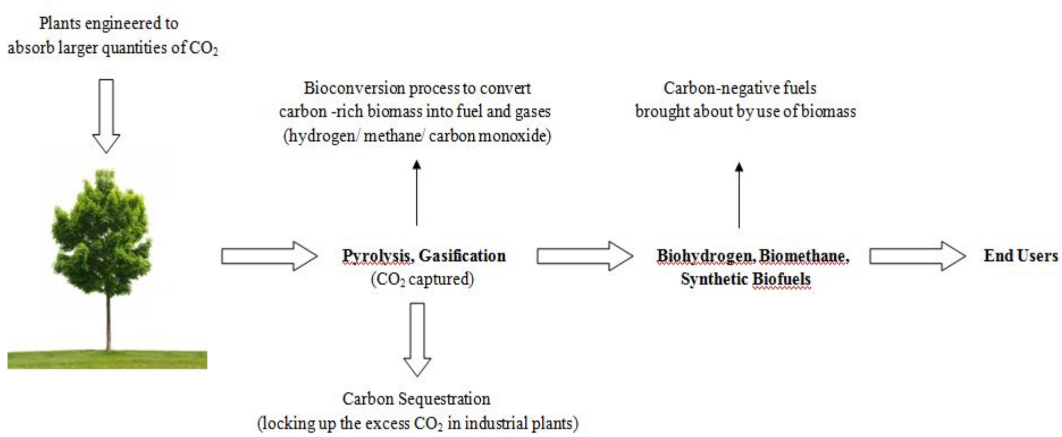
biofuel are neutralized. This costly option would also be unsuitable for developing countries facing water shortages. Furthermore, the algae's lipid is known to be "highly unsaturated" [10]andcan degrade at higher temperatures, affecting automobile engines in the long term. As such, the possibility of third generation biofuel being made commercial is still highly unlikely.

Fourth Generation

Dubbed as the most recent brainchild of the Biofuel industry, fourth generation Biofuel also employs algae but combines it with metabolic engineering processes (Figure 1).With the biomass derived from crops, they are broken down by enzymes into sugars and microbes are then employed for fermentation to convert the biomass to biofuel [11].As mentioned by Jing et al. [12], the presence of oxygenic photosynthetic microorganisms is necessary and plays a huge role in making biofuel conversion possible, together with abiotic factors like sunlight, water and CO_2.With CO_2 produced, the algae are responsible for performing carbon sequestration, thus significantly reducing the amount of CO_2 that would otherwise be released into the atmosphere [13]. Once CO_2 is obtained, it is stored away in industrial plants like saline aquifers, to be used by algae later. Thus, the author in [14] highlights that fourth generation biofuel is said to be carbon-negative, having substantial positive impacts on the environment. Furthermore, the cultivation of algae eradicates the cultivation and usage of food crops, which does not require arable land, preserving biodiversity in its natural form. However, despite the supremacy of utilizing fourth generation biofuels, extremely high capital needed for research and development is a major hindrance to being a viable yet cost-competitive option. In [15], the production cost per gallon of biofuel is estimated to be between US$6 and US$7, more than half the cost of producing first and second generation biofuels, at US$3 per gallon or lesser.

Figure 1: Simplified Technological Process of Fourth Generation Biofuel



Source: Biopact, 2007

III. ADVANTAGES AND DISADVANTAGES OF BIOFUEL USAGE

Despite eminent advantages, the substitution of fossil fuels with biofuel has undoubtedly sparked controversy and long been in debate. Avid supporters would argue that switching to biofuel supports Mother Nature, while skeptics retort that its production process is too cost extensive. Furthermore, apart from risking potential environmental degradation by exceeding the sustainable yield of crops for food, the immense amount of energy used in production eventually negates its benefits.

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Advantages

Environmental Impacts

Biofuel, especially biodiesel, is gaining popularity as a more environmentally friendly alternative to fuel mileage. Prominent car manufacturershave since hopped onto the bandwagon by remodeling diesel engines to ensure compatibility with operating characteristics of biodiesel. A study by the Argonne National Laboratory[16] has proven that biodiesel reduces carbon footprint by up to 41%, effectively being less harmful to the atmosphere. Despite a slight increase in the NOx emission, [17] shows that this minor drawback is superseded by the considerable decreases in other major GHGs, such as PM and CO by up to 50%, proving that biodiesel is still the greener alternative. Furthermore, biodiesel's high flashpoint of 130°C impedes ignition processes in the engines during regular automotive usage, resulting in less risk of producing toxic gases, in comparison to petroleum diesel's lower flashpoint of 52°C [18]. As such, the usage of biofuel can significantly slow down the rate of the Earth's atmospheric degradation, towards helping Mother Nature restore its natural balance.

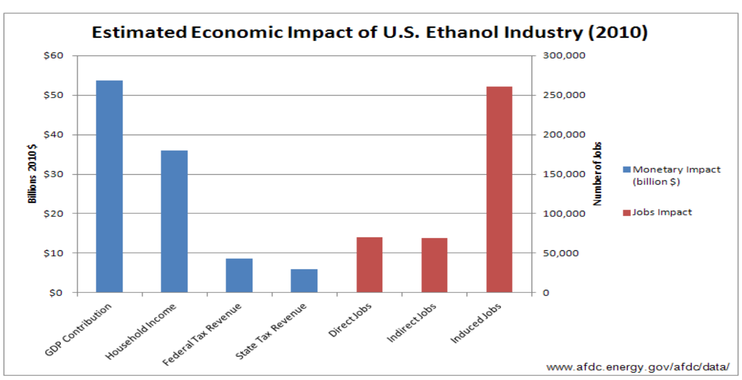
Health Impacts

In America, considering her vast land availability and population, owning a car is a necessityand has taken commonplace. Thus, a whopping daily consumption of 21 million barrels of regular gasoline fuels approximately 244 million vehicles. With the inevitable release of toxic particles from fossil fuels, the catastrophic effect is ranked 7th on the global death list, responsible for 3.2 million deaths from respiratory complications in 2010 alone [19]. In addition, it was proven that a pregnant lady's constant exposure to emitted gases could also result in the alteration of the fetus' DNA. Considering the severe health implications detrimental to society's well being, the demand for biofuel has become popular since it discharges less soot and carbon emissions, reversing poor air quality. Furthermore, biodiesel is free from sulfur and benzene, which are linked to respiratory diseases and cancer respectively [20].

Economic Impacts

With reference to the National Biodiesel Board [21], biodiesel production alone benefits the American economy, grossing annual revenue of USD$4.287 billion and counting. Due to the labor-intensive production and America's need to uphold her status as a global biofuel power, alarge-scale manpower base is needed. According to [22], an average of 16.455 jobs are created per 100 million gallons of biodiesel produced, producing a total of 1.4 million jobs. This would also shrink economic gaps. With a sturdy biofuel industry(Figure 2), there would be more investments from firms, regulating better economic flow [23].Furthermore, there would be a greater demand for feedstock. This provides economic opportunities for developing countries, which base their economy largely on agriculture. Thus, the biofuel industry presents lucrative economic benefits.

Figure 2: How Biofuel has Positively Impacted the U.S Economy



Source: U.S Department of Energy, 2013

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Disadvantages

Environmental Impacts

Deforestation

The establishment of feedstock on forestland would lead to deforestation through the displacement of pasture, based on the author in [24].Feedstock used for biofuel would have primarily been used for growing of food to feed the human population. When demand for biofuel rises, feedstock reserved for consumption would then drop. Thus, to cope with the rising feedstock expansion and food prices, more land has to be cleared. Deforestation practices also results in soil erosion, land and water pollution and also fragmentation of natural habitats that cause loss of biodiversity. This is already a problem in Brazil, where land is obtained at the expense of terrestrial ecosystems like grasslands and amazon rainforests. She is currently known to be a global “leader in annual deforestation”, with the purpose of biofuel crop growth as one of its priorities [25]. For example, 50% of Brazil’s largest savanna in The Cerrado, home to 5% of Earth’s plant population, has been cleared to grow sugar cane crops and will continue at a yearly rate of 1.5%. Thus,as mentioned by the author in [26], deforestation issues are magnified, exploiting nature’s resources.

Land Degradation

Nutrient depletion is another form of land degradation whereby the fertility of the soil is affected due to continuous farming of biofuel crops. To counter this problem, commercial fertilizers are utilized to increase the yields of crops and speed up harvesting processes. However, these fertilizers have side effects due to chemical content, ultimately affecting soil quality. Thus, the land eventually becomes non-arable. Prolonged use of fertilizers would damage the soil and living organisms within, which are also essential to soil productivity [27].

Social Impacts

Food Security

With increased need for crops due to greaterpopularity of biofuel, food security becomes a pressing issue as the amount of food set aside for the human population has dipped,especially in developing countries. Citing grain food such as corn, barley, and milled rice as an example, the percentage of grains used for biofuel production went up six-fold from 1% to 6% in a decade (Figure 3) [28].In India, despite having vast land to grow daily necessities like rice, she still imported “2.2 million tons of wheat” in 2006 [29] to feed herpopulation. Judging India’s food struggle, the population will suffer more if more crops are siphoned away for the continuous expansion of the biofuel industry. In addition, the author in [30] emphasizes that scientists have deduced that global warming would jeopardize crop yield by up to 2% per decade. More people will die of malnutrition since there will be a further deficit in food supply. Thus, all these activities result in a plunge in food availability, promoting poverty. With all these biofuel related factors working against India’s favor, food security is shaken.

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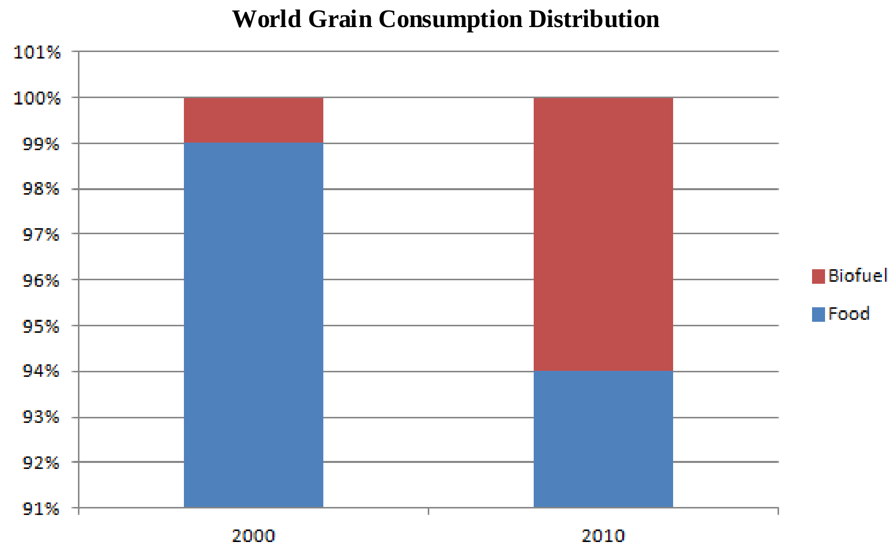
Figure 3: Increasing Proportion of Food Diverted towards Biofuel Production



Source: Nestle, 2011

Economic Impacts

Rising Food Prices

Judging from a dip in available crops for human consumption, the rise in prices of existing food quantity is imminent and eventually becomes a fight for the survival of the fittest among the population[31].Citing America and the European Union as examples, [32] shows the that production of maize over a period between 2004 and 2007, skyrocketed by a shocking figure of 40 million tons, of which 70% was used for the production of Bioethanol. This shift resulted in the increase of 30% in cereal prices, sparking much controversy. Furthermore, to support massive production of maize, 30% of land used for soybean production was converted to maize, resulting in an increase in prices of soybean by an immense 75%. Again, from [32], it is concluded these price hikes would surely take a negative toll on the welfare and societal happiness of the states and also result in inflation.

IV. CASE REVIEWS EXPLORING BIOFUEL INDUSTRY

Germany's Use of Biofuel Technology

Acknowledging microalgae's extensive benefits for nutrition purposes, pharmaceutical resources and also renewable biofuel reserves, Germany has spent much time and effort in the research for microalgae's most efficient production processes. She is indeed a market leader, having a combination of cutting-edge technology, bountiful financial resources and also the influx of human expertise, companies have obtained research patents to sustain the development of fourth generation biofuel. Using Flat Panel Airlift (FPA) bioreactors (Figure 4), which is the product of German research and technology, cultivation of algae is made possible through these main steps:

Firstly, algae is collected and isolated in a liquid algae bank where they will be further modified through genetic engineering, increasing their cellular productivity. This would ensure exploitation of maximum biomass yield. While in the FPA bioreactors, the algae matter is exposed to abiotic factors like solar energy, CO_2 and water. These bioreactors are uniquely designed in such a way that CO_2 in industrial exhaust can immediately and effectively travel through attached closed tubes and columns, quickly reaching algal matter enclosed in banks.This CO_2 can also be stored in the bioreactors themselves and be reused whenever necessary. In addition, these tubes and columns also help to control the

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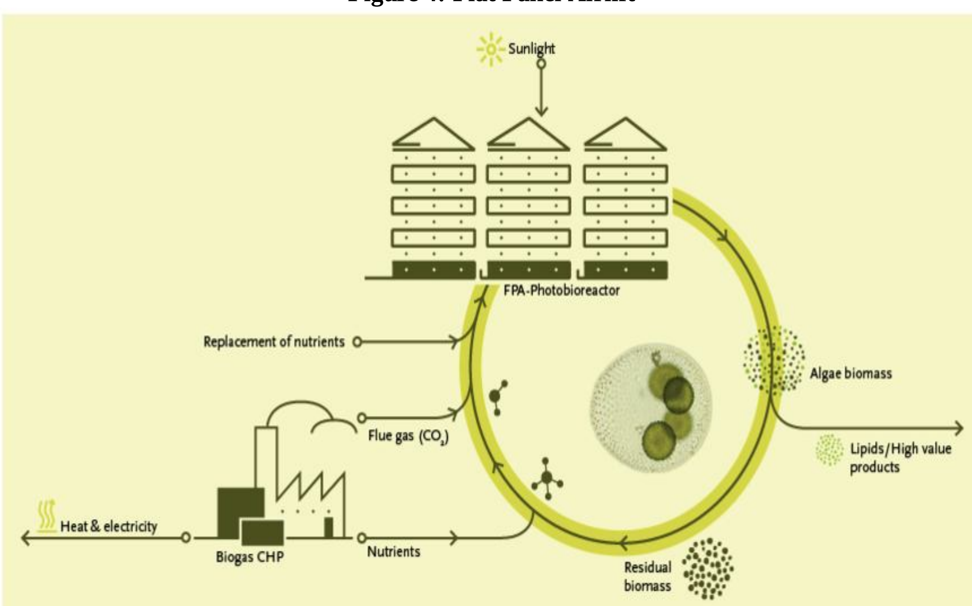
intensity of exposure to the algae's abiotic nutrients, while providing a protective shield from the atmosphere, minimizing any form of external bacterial contamination. The presence of a self-contained cultivation system allows adequate distribution of necessary nutrients for algae growth. Furthermore, from [33], its massive volume of 180 litres gives rise to productive mass cultivation, multiplying available yield.

Apart from tubes and columns, there are also exclusive plate reactors, which are purely responsible for the balanced circulation of solar energy to all algae cells. Divided into 3 sections of varying light concentrations from light to darkness, the intensity of light energy is controlled through streams induced by static mixers. Thus, considering the ideal structure within a bioreactor, algal matter can be extensively cultivated and ready for purification and extraction purposes [34]. Once enough algal lipid is derived, fourth generation biofuel and biogas are produced.

In addition to FPA bioreactors, German technology also makes use of massive biogas plants to support the nation's high and increasing demand for biofuel. Due to the highly powered electrical make-up installed in these plants, [35] states that the biogas produced is so impactful that it is able to generate as much as 8.4 million kilowatts of combined heat and electricity yearly, which is equivalent ofutilizing 440,000 litres of regular fuel oil.These environmental improvements are undoubtedly only made more attainable due to constant research and development efforts in Germany. Also, like the bioreactors, these airtight biogas plants collect an abundance of various organic matter, providing sufficient nutrients for anaerobic microbes to produce biogas during digestion processes.

Due to the FPA bioreactors being capable of "high volumetric productivity"in an environmentally friendly way, while keeping capital and operational costs low and also various other facilities as a result of technological advancement [36], Germany is indeed a leading giant to look up to in the global biofuel industry.

Figure 4: Flat Panel Airlift



Source: Subitec GmbH Stuttgart

America's Advancement In Algae Biofuel Technology

America's quest to commercialize algae biofuel has been a tumultuous journey, especially having given up on the research-based Aquatic Species Program (ASP) in 1996, factored by the authors in [37] to its cost intensive nature being too much of a burden to bear. However, due to the growing concern regarding the depletion of non-renewable fossil fuels at an alarming rate, a much cleaner energy alternative had to be derived. Since 2000, a whopping USD$2billion of private funds has been invested to aid development [38]. In addition, considering another recent

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USD$22 million of funding [39], it is no wonder that America beat other continents like Europe, Asia Pacific and Africa with 70% market funding rates (Table 3)[40].

Table 3: Level of Participation by Various Countries in Algae Biofuel

Table 1.1 Average Score by Region and Assessment Framework, World Markets: 2013*

Region	Liquid Fuel Demand	Feedstock Opportunity	Marke Demand	Market Investment
North America	42%	64%	30%	70%
Western Europe	9%	48%	52%	55%
Eastern Europe	3%	46%	51%	33%
Asia Pacific	15%	41%	34%	29%
Latin America	4%	40%	29%	15%
Middle East & Africa	2%	38%	22%	13%

(Source: Navigan Research)
* Average regional score relative to maximum.

Source: Environmental Leader LLC, 2013

Being "the dominant force in advanced biofuels market", majority of biofuel projects in the world are based in America. Having produced 132 million gallons of biodiesel in the last quarter of 2013, this amount was 75% higher than the production yield a year ago. As such, from [41], America is well on herin meeting the America's Renewable Fuel Standard of 22 billion gallons of algae biofuel by 2022.This of course, does not come without disadvantages. Given the current standards of technology in advanced algae biofuel, immense amounts of inputs are required, including water and nitrogen to facilitate the growth of algae. This may result in unsustainable growth as water is a precious resource that is not inexhaustible. Needless to say, there is plenty of room for further improvement and strategies to counter this problem are still undergoing research. Mentioned by the author in [42], these strategies include processes to recycle water and nutrients to ease the burden of using new resources, which would otherwise accelerate the depletion of the resources.

Although algae biofuel is considered to be a product of superior technology, the extraction process of lipid from algae still has not been entirely perfected. This is because amount of lipid produced is inversely related to the access to nutrients, meaning that if the algae are starved of nutrients, it would produce lipid at a faster rate [43]. However, this deprivation of nutrients would result in the hindering of the algae growth rate. This contradicting problem is the main obstacle to enabling algae-derived biofuel to be commercially viable, as the author in [44] highlights that both the quantity and rate of production of lipids need to be at the optimumlevels. In recent years, Scripps Institution of Oceanography at UC San Diego has conducted studies, allowing researchers to derive greater lipid mass from microscopic marine algae. By specifically targetingan enzyme in algae known as diatoms, and performing "metabolic manipulations",a greater lipid yield was obtained without compromising the growth of the algae [43]. In the long run, greater growth and enhanced lipid accumulation is beneficial for cost effective biofuel production. This breakthrough is indeed a significant milestone reached by America and is a catalyst for more research collaborations to achieve preeminent advancements.

Singapore's Stepping Stone Towards A More Sustainable Future

Known as the 'red dot' on the world map, Singapore is a very small but yet, developed country. The commercializing of biofuel in Singapore for local consumption is still very minimal, with only small-scale operations running. One such operation is Biofuel Research Pte Ltd [45], the pioneering biofuel company in Singapore, founded in 2003. Biofuel Research made their breakthrough developing a waterless means of producing biodiesel from vegetable oil by-products and non-food oils such as sewage grease in 2008. Following this successful discovery, Biofuel Research was granted

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funding under the Startup Enterprise Development Scheme (SEEDS) from Spring Singapore, an agency under the Ministry of Trade and Industry that facilitates the growth of businesses with innovative and promising products [46].
Another locally operated biofuel company is Alpha Biofuels, which started up in 2004. Alpha Biofuels [47] has micro-refineries which allow small-scale conversion of waste cooking oil to biodiesel that is fully compatible with diesel engines. With over 200 business partners contributing waste cooking oil, Alpha Biofuels has managed to produce biodiesel for local companies such as taxi companies and Singtel, a telecommunications service provider in Singapore. Alpha Biofuels also has overseas projects where its micro-refineries convert waste cooking oil into biodiesel to power generators for local infrastructure. One such example is in Cambodia, where waste cooking oil from hotels in Siem Reap is recycled to make biodiesel for the Angkor Hospital for Children to provide electricity [48].
In terms of foreign investments, Singapore has had success in attracting foreign biofuel giants, such as Natural Fuel Limited, an Australian-based renewable energy company and Neste Oil, a Finnish oil refining organization. Both companies have established biofuel plants in Singapore, with massive capabilities of producing 600,000 and 800,000 metric tonnes of biofuel respectively per annum [49]. Thus, this has increased Singapore's biofuel production capacity tremendously and allowed Singapore to stamp her mark on the global biofuel distribution market.
Neste Oil in particular, is the world's leading renewable diesel supplier as well as a pioneer in producing biodiesel for the aviation sector. Its success comes from their NExBTL technology [50] which makes use of 100% renewable inputs such as a wide variety of vegetable oil and waste materials. Thanks to its chemical composition, biodiesel produced from NExBTL technology is also compatible with majority of modern diesel engines, with the added advantage of a much lower carbon emission rate of about 24% [51]. While Singapore has yet to supply biofuel to her domestic market on a large scale, she has certainly established a strong foothold in the biofuel industry and shows great potential in the market.

Brazil Stuck On First Generation Biofuels

Brazil is also among the largest producers and consumers of biodiesel in the world with an annual production in 2010 of 2.4 billion litres and an installed capacity in the same year of 5.8 billion litres, according to the Brazilian National Agency for Petroleum, Natural Gas and Biofuel [52].While Brazil is one of the largest biofuel producers globally, the bulk of their biofuel derives from first generation biofuel, namely sugarcane. As a developing country, one of her main concerns is achieving energy securityas well as the benefits of 'flex-fuel vehicles', which also increased domestic consumption of ethanolfrom sugarcane[53]. This has led to the large-scale production of vehicles that are flex-fuel compatible, being able to run on any combination from hydrated alcohol and gasoline, according to the author in [54]. As such, it has been projected that Brazil's domestic ethanol use would reach 40 billion litres by 2021.
Another major factor driving the ethanol industry is that following China, Brazil also has a very low ethanol production costat $0.18 per litre (Table 4) [55]. The residual sugercane biomass has a secondary use of producing electricity, known as cogeneration. Cogeneration is the "simultaneous production of electricity and heat from a single fuel source", which includes biomass [56].With mass expansion of sugercane production since the 1980s, the production of electricity from crushed sugercanes had grown exponentially.It was estimated by authors in [57] that in 2007, 3% of total electricity production was contributed by cogeneration from sugercane biomass and will grow to 15% in 2015.
Brazilian biofuel has already been classified as one of the greenest biofuel with greenhouse gas reductions of up to 60% compared with gasoline [54]. Coupling this with the fact that Brazil's soil and climate is suitable for sugercane growth, Brazil has little interest in exploring the development of cellulosic biofuels. The ten year plan formulated in 2012 also proves that the Brazil government has no intention of pursuing biofuel production past the first generation.

Table 4: China's Production Cost of Ethanol/Litre in Comparison to Other Companies

Country	Amount Produced (litres)	Cost of Production (/litre)
United States	19,973,066,500	$0.33 - $0.47
Brazil	16,999,949,000	$0.18 - $0.20
European Union	3,397,416,000	$0.50 - $0.97
China	3,850,102,000	$0.17
India	1,900,070,000	$0.46 - $0.50

Source: Institute for Energy Resourcefulness, 2013

Africa's Potential in Biofuel Production

There is much interest in the biofuel scene in Africa as the government is concerned about energy security, oil prices and climate change. Based on [58], biofuels may be the only solution to overcome these concerns for the country. The Republic of South Africa, Department of Energy introduced a five year pilot phase in 2007 for biofuels production with a goal to hit a 2% penetration of biofuels in the national liquid fuel consumption pool which did not turn out to be due to the lack of investors [59]. Since then, Africa has remained at the sidelines of producing biofuel due to uncertainties in demand for biofuel worldwide, despite having a favorable climate, affordable labor and an overflow of resources [60].

The division of energy used in Eastern Africa is dominated by biomass such as wood and charcoal as there is limited access to modern energy sources and technology to produce advanced generations of biofuel, according to the author in [61]. With the low cost and abundance of labor, Africa focuses greatly on the first and second generation of biofuels, with sugarcane as the main ingredient for ethanol production and more recently, Jatropha biodiesel. Comparing jatropha energy returned on energy invested (EROI) with sugarcane, a meta-analysis by Stromberg and Gasparatos [62] report that the EROI for sugarcane bioethanol is 3.1 to 9.3 whereas EROI for jatropha oil is 1.4 to 4.7. This ratio concludes that jatropha oil has a higher yield as compared to sugarcane bioethanol. As such, this is a push factor that Africa considered when investing in Jatropha. Within the pool of developing countries, biofuels in Africa is considered as a catalyst to stimulate growth in many other economic sectors [63]. In [64], Africa can use the recent increase in demand for biofuel to meet the United Nation Millenium Development goals of decreasing poverty with the potential increase in jobs due to the increase in the production of biofuels.

There are many biofuel projects in Africa and can be divided into four main types with each type segregated based on the production and intended usage of the biofuel[63]. Africa is making its stand in the usage of biofuels and announced that they will start blending biofuels with gasoline and diesel by October 2015 [65]. However, the authors in [66] highlights that there is a continual issue with regards to food production and prices with the increase in biofuel production, contributing to the spread ofhunger.Still, authors in [67] notes that Africa definitely has a significant potential to develop the biofuel industry attributing to its vast arable land available andadequate precipitation to sustain biofuel production.

China’s Advancement in Biofuel Technology

China’s biofuel scene is steadily expanding since its very first ethanol project in 2001[68]. Despite the presence of four different generations, China's main focus is on the first and second generations. Compared to other regions actively producing ethanol, she boasts of lowest ethanol production costs worldwide, at merely $0.17 per litre (Table 4) [55], becoming a very attractive energy source for many. This may be an indication of why she is so heavily dependent on first generation biofuel due to its relatively low cost. Furthermore, since biofuel is mainly a product of feedstock and judging from the rising demand of biofuel, [69] remarks it acts as a catalyst for existing agricultural economic growth in China, in addition to other developments in the automotive and chemical industries. The focus on first and second generation biofuel may also stem from the fact that lofty crop harvests are both socially and financially beneficial for many Chinese rural communities. With the rising demand for crops, there will naturally be a greater volume of job opportunities, multiplying the annual incomes of farmers.

On the other hand, China’s recent goal of utilizing 5 million tons of bioethanol fuel by 2015 has led to various problems, one of which being a shortage of additional land to grow more crops [69]. According to statistics [70], she currently has only 1.1 square kilometers of arable land, falling short to biofuel giant, America, with 5.6 square kilometers. Also bearing in mind certain limitations like land scarcity and food security due to the need to feed its growing population, she faces hindrances in the expansion of biofuel supply.

In terms of technological breakthrough, there have been promising results from the Aviation sector. Recently on the 12th February 2014, China's top oil refiner, Sinopec, was granted the license for airlines to commercially run their aircrafts on its self-developed aviation biofuel, the first of its kind in China [71]. While it has not yet arrived at the stage of large-scale commercialization due to it being more costly than conventional fuel, it still marks a milestone reached.

There has been minimal progress of third and fourth generation biofuel despite ongoing research efforts. The Qingdao Institute of Bioenergy and Biotechnology was set up in 2006 to develop bioenergy infrastructure. Although there have been few projects carried out to research on the development of algae for biofuel [72], China is in a long way from commercializing third and fourth generation biofuel.

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Indonesia's Biofuel Dilemma: Economic Opportunity or Deforestation Driver?

Being the leading producer of palm oil, Indonesia is at the position of potentially deriving the largest amount of biodiesel from its supply of palm oil, contributing to over 700,000 tons of palm oil-based biodiesel produced in 2007 [73]. However, a directive formulated by the European Union puts Indonesia's biofuel industry in jeopardy. In [74], One of the criteriaimplemented is that the land which biofuel feedstock is cultivated in must not have high carbon stock.Having to comply to these stringent standards, would unfortunately render the majority of palm oil produced in Indonesia as undesirable solely because of its method of production.

It must be noted that since Indonesia is still very much a developing country, there are limited technological resources to make any significant advancements in the biofuel industry. Thus, only first generation biofuel is currently fully commercialized and efforts to research on second generation are ongoing [73].Due to the rising costs of burning fossil fuels, Indonesia sought out the alternative of biofuels in 2006 as a potential future source of energy to meet the increasing demands for domestic consumption of oil. In an attempt to capitalize on the emerging market of biofuel, as well as mitigate the cost of importing oil, Caroko et al. [75] comments that Indonesia has developed plans with the intention of increasing biofuel consumption to 5% of national energy consumption by 2025. This is further aided by the extensive palm oil plantations found in the country to fuel such a major goal.

Despite vast availability of plantation, biofuel companies still have to resort to renting land from the locals to expedite the crop yields in order to satisfy continuously increasing demands. This has created a win-win situation whereby biofuel companies now have sufficient land while creating income opportunities for locals to improve their standard of living. The projected trajectory of Indonesia's biofuel consumption has only one direction; upwards. With policies strengthened by the government to reduce costs on gasoline imports, Jaipuriyar et al. [76] notes thatinvesting in the biofuel industry is indeed beneficial for Indonesia's long-term economic growth by being self-sufficient in biofuel production.

Unavoidably, drawbacks are to be expected. In the case of Indonesia, deforestation is a major impact brought about by the expansion of the biofuel industry. With the highest rate of deforestation in the world, an estimated loss of 2.3 million hectares of forest between 2000 and 2012 has been reported, with only 800,000 hectares gained back [77].Substantiated by a study conducted by Greenpeace, where biofuel production from palm oil accounted for approximately 25% of total deforestation causes[78].Between 1985 to 2001, it was recorded by [79] that over 56% of protected rainforest was cleared, amounting to 29,000 km^2, attributed by the expansion of oil palm plantations being a major driving force of deforestation when the industry grew from 600,000 hectares in 1985 to 6 million hectares in 2001.With a rise of carbon emissions that further impacts climate change, this calls into question the sustainability of Indonesia's biofuel production. If Indonesia wishes to continue to expand on her biofuel industry, much effort needs to go into ensuring that the negative impacts are not neglected and further generations of biofuels ought to be explored.

India's Solution To Sustainable Biofuel Production: Jatropha

India has a population of 1.147 billion people, making it the second most populous nation in the world [29]. Thus,she has been labeled as the fifth largest energy consumer in the world and with the ever-increasing energy demands in recent years, India has turned to importing energy to meet those demands. Experts have predicted that the purchase of crude oil from around the world in India will rise to a massive figure of 94% by 2030[29]. Biofuel offers potential opportunities to decrease India's reliance on foreign countries for oil import.

Currently in India, sugarcanes are the most common feedstock for biofuel production and there are concerns arising with regards to food supply to feed her massive population. Research shows that India has been ranked the second largest consumer of sugar in the world with a statistic of 15, 588 thousand metric tonnes from [80]. Facing this issue, the government of India approved the National Policy on Biofuels in December 2009, proposing a target of 20% biofuel blending of both bio-diesel and bio-ethanol by 2017 [81]. Moving ahead with this policy, the government launched the National Bio-diesel Mission (NBM), identifying a new feedstock called jatropha as being ideal for bio-diesel production. India's government have identified approximtely 100 million acres of land that could grow jatropha [82].

Moving into the second phase of India's biofuel revolution, the second generation, jatropha has many advantages over other feedstock. It is not only adaptable in harsh environmentswith minimal water and nutrients, but also yields huge harvests of an estimate amount of 1,892 litres of oil per one hectare [29]. In addition, jatropha oil has proven to be eco-friendly by creating a closed cycle of CO_2. The closed cycle is created as such that when the oil is burned;CO_2 is released and absorbed out of the atmosphere when the next crop of jatropha grows as explained in [83]. The decidingfactor to conclude it as an ideal feedstock for biofuel is the fact that jatropha is a non-food crop and would hence, have no direct impact to food security.

An estimated 27% of Indians live below the poverty line and India has to import 2.2 million tons of wheat in order to ensure food availability [29]. With the cultivation of jatropha oil, it would curb the rise of food prices in India by eliminating the need for using staple foods such as sugarcane in India for energy demand. This helps with the current economic situation in India, as the cultivation of jatropha will increase job opportunities for local farmers, thus alleviating the issue of poverty in India.

However, local farmers might be against the idea of cultivating jatropha in which the government has to find a way to show that benefits of supporting the advancement of biofuel to tackle the problem. Although the government has to step up and establish Minimum Support Prices and Minimum Purchase Prices [29], further ways have to be continuously explored in order to convince local farmers to accept the cultivation of biofuel feedstocks.

V. RECOMMENDATIONS

With regards to third and fourth generation biofuel, it all boils down to which is a more viable option as a futuristic source of energy. Both generations have been established as land-friendly sources,meaning that they do not actively compete for arable land with existing agricultural activities and produce significantly higher yields than prior biofuel generations, which puts them in the leading position of all four. However, having been developed much earlier, third generation biofuel has posed several drawbacks, such as requiring a tremendous amount of water to cultivate algae needed for biofuel production. In addition, in order to speed up growth processes, massive amounts of fertilizers are needed, causing additional environmental damage, as discussed earlier on.

In the case of fourth generation biofuel, the major concern is that it is a relativelymodern development.Thus,it lacks in intensive research, whichgives rise to doubts aboutits feasibility as the future chief energy source. With that, more funds have to be pumped in to encourage scientific experimentation.Nonetheless, we can still be certain of various elements. For example, in [84], it has been proven that the fourth generation biofuel production results in a carbon-negative situation, instead of simply being carbon-neutral, which eventually makes it a better contender as compared to third generation biofuel. Thus, it is obvious as to which process the world should aim to make use of.With that being said, the state of technology and land space that is available in each of the countries has to be considered and may still be a stumbling block for some, especially in developing countries. For example,the usage of first or second generation biofuel production in Africa or Indonesia is more feasible and realistic due to factors like vast land spaces, influx of manpower and shortage of financial or professional resources. They can hope of using the more advanced generations, only if they escape from the clutches of underdevelopment.The privileges of using third or fourth generation biofuel would be more applicableto developed countries likeGermany or America, or even Singapore, as all three countries have the technological and financial resources available to further their research in advanced biofuels even with the lack of human resources.

In the long run, we believe that the fourth generation biofuel provides the most promising and environmentally beneficial returns. Advancements in state-of-the-art technology and new discoverieswould soon shed more light on its likelihood of global commercialization. Coupling this with the current advantages already made known, it is only a matter of time when a breakthrough is made and the previous three generations of biofuel would be surpassed.

VI. CONCLUSION

Judging from the disadvantages of biofuel, its most impactful environmental benefit will still be neutralized to a certain extent due to the extensive use of fertilizers in order to increase the yield of crops and algae growth for production. In addition, research has proven that the cost of production per unit is currently higher than that of usual petroleum, which might still be a factor as to why people are still hesitant to make the change. However, we must always bear in mind that the result of using biofuel is environmentally friendly in the long run due to its lowered greenhouse gas emissions. Thus, that should be the focus of converting to biofuel to contribute significantly to a more sustainable world for future generations, making these positive impacts the lesser of both evils. While cost is inevitably always factored into decision making by all businesses, it is secondary to the importance of conserving planet Earth. Money can always be earned back but if we were to lose our environmental resources, we may not be able to regenerate what has been lost. Some environmental damages are unfortunately irreversible and prevention is always better than cure. Furthermore, it

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is society's responsibility to care for Mother Nature, also indirectly improving the quality of life for both mankind and animals.

In addition, nothing is without consequences and society always has to be conscious of the bigger picture. Based on the fact that fossil fuels are non-renewable reserves, logic dictates that fossil fuels will eventually be diminished and no longer be mankind's go-to source of energy. Biofuels, on the other hand, will definitely be staying for the foreseeable future and can still continue to provide the earth and the human population with a relatively clean source of energy with several benefits such as economic benefits of providing employment and health benefits of reduced carbon emissions, leading to cleaner air. Moreover, scientists' perpetual quests for improvements to biofuel technology, proven by the discovery of the four generations, are a pull factor. With increasing sophistication of technology and intense research and development done, one can safely infer that biofuel will become more appealing and applicable to be used on a globally commercial level.As such, biofuel is acknowledged as the Earth's future energy source. Until such time where a newer and cleaner source of energy is discovered, scientists will definitely persist to research and enhance biofuels to make them more cost-effective, while still being environmentally friendly.

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